Use of the Rocking Bed to Augment Ventilation in Patients with Poliomyelitis

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SUMMARY

As the first step in an attempt to clarify criteria for use of the rocking bed rather than the respirator as an aid to breathing for patients with weakness of respiratory muscle function caused by poliomyelitis, ventilation studies were done on seven patients with pronounced weakness or paralysis of the respiratory muscles. Average tidal air volume was considerably less when the patient was on the rocking bed than when he was in the respirator. Since the tidal air volume with the patient on the rocking bed represents the maximum that can be produced with the apparatus, whereas the volume in the respirator represents the patient's usual tidal air and the respirator is capable of a greater volume if necessary, it is apparent that in cases of complete paralysis of the respiratory muscles the respirator has a large margin of safety, the rocking bed none.

From clinical observations made on 51 patients who were put upon the rocking bed—23 of them early in the course of the disease and 28 after they had been ill three months or more—it was concluded that the rocking bed is contraindicated for patients who are febrile and in whom the disease is progressing rapidly, and for those with atelectasis or urinary or pulmonary infection. It must be used with extreme care in the case of patients early in the course of the disease who are not tracheotomized, because of a tendency toward increased accumulation of mucus and the danger of atelectasis.

General guides were developed with regard to use of the rocking bed for patients with post-acute poliomyelitis, and somewhat different rules were drawn for use of the apparatus in cases in which there is a chronic respiratory problem.

The rocking bed will give artificial respiration in cases of respiratory weakness, but will not provide enough tidal air for the patient with paralysis of the muscles of respiration.

IN 1932, Eve[3] reported the use of a rocking stretcher for resuscitation. The patient was tilted from head to foot about 30° each way at a rate corresponding to that of natural respiration. The artificial respiration thus produced was sufficient to overcome pronounced respiratory distress and inadequacy. Eve reported using this method in two cases. In one case the patient was a small girl with post-diphtheritic paralysis of the diaphragm, and respiration was maintained for two or three days until there was adequate return of function in the diaphragm. Since that time, Eve has advocated the tilting stretcher for use in resuscitation, especially of the drowned, with tilting ranges up to 45° each way. The method appears to be more effective[1, 4] than those of either Schaefer or Silvester.

Since Eve's report in 1932, the rocking principle has been used in the treatment of peripheral vascular diseases.[8] The rate of motion of the Sanders bed, as well as its tilt, is much less than is necessary to produce any appreciable ventilation.

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Aided by a grant from the National Foundation for Infantile Paralysis, Inc.

Recently Wright[9] and Lenarsky[6] have advocated the use of the rocking bed in poliomyelitis with complicating respiratory insufficiency to aid in ventilation as well as to improve circulation and muscle function. A visit by Dr. Wright to the Los Angeles County Hospital and to the Rancho Los Amigos in 1949 stimulated the authors' interest in the use of the rocking bed in poliomyelitis. It is the purpose of this report to describe experience and experiments with the apparatus and to give criteria for its use based upon knowledge of the deficiencies of respiration as observed in the large number of cases of this type in Los Angeles County during recent years. The report deals primarily with the problem of inadequacy of ventilation. It does not attempt to establish the effect of the bed on circulation and muscle function.

TIDAL VENTILATION MEASUREMENTS

The effect of the rocking bed on breathing depends on the shifting of the abdominal contents that results from alternately lowering and raising the head of the patient. This shifting rhythmically elevates and depresses the diaphragm and consequently causes an appreciable tidal exchange of air. The effectiveness of respiration thus produced can be

evaluated by measuring the tidal air volume. It is probably impossible to measure this volume in the subject while he is awake or even during narcosis as long as the respiratory center can have any effect on breathing. The importance of this factor has been emphasized by Henderson.[5] To overcome this, Macintosh and Mushin[7] rocked two deeply narcotized subjects while spirometric measurements were made. One of the subjects was 140 pounds and the other 182 pounds in weight. With a tilt of 30° each way, a total of 60°, and a rate of 10 per minute, the tidal air values were 240 cc. for the smaller patient and 570 cc. for the larger. With a tilt of 45° each way, a total of 90°, the values were 380 and 635 cc. respectively. It should be remembered that the subjects did not assist or hinder breathing.

To better evaluate the ventilatory capacity of the rocking bed, it was decided to make spirometric measurements on patients with practically complete paralysis of the muscles of breathing. It was felt that this study would give further information about the properties of the beds available for clinical use, not just for the normal subject, but for patients of the type for whom the bed is intended. It is hoped that the results of these determinations and the clinical observations in the therapeutic use of the bed will lead to practical criteria for the safe use of the rocking bed in ventilatory deficiency.

Two types of rocking beds were employed in this study. They consist essentially of the usual Gatch type springs mounted on a mechanism to produce rocking from head to foot at a rate corresponding to respiration. One type* pivots at the top and center of the mattress, a mechanism made possible by a special tracking design. The speed and degree of tilting are adjusted by remote control on a separate panel. The tilt may be varied from 0 to 22° each way, a total of 44°, and the speed to about 24 oscillations per minute. This is the type of bed used by Dr. Wright.

The other bed† has a compound pivot so that besides rocking from head to foot there is also a lurch which appears to contribute to its action. The rate of oscillations can be varied from 12 to 24 per minute. The total tilt is about 35°, but the effect on respiration is about the same as that of the McKesson bed because of the compound action. The total tilt can be varied but slightly; however, the relative dip of head or foot can be varied. The Painter bed is mechanically controlled and is a single unit.

Spirometric measurements were done with a commercial metabolism apparatus‡ which was converted by removal of the unidirectional air valves and the insertion of a ventilating fan in the closed air circuit. A few readings were done with a spirometer§ modified to make tidal air determinations.

Nine tidal ventilation readings were done on seven patients who were practically completely paralyzed, but who had been well otherwise and whose condition had been unchanged for many weeks. Two patients had zero vital capacity, one 30 cc., one 40 cc., and the other three about 100 cc. The meager ability of some of these patients to breathe depended on action of the accessory muscles in the neck, a factor which could be easily watched and discounted during testing. The tidal air was measured while the patient was in the respirator which was set at the pressure used for the patient day and night. It should be observed that these readings indicated fairly closely the need of the patient, since any prolonged excess or inadequacy of respiratory volume would be reflected clinically. Comparison of these volumes with those produced by the rocking bed would aid in the evaluation of the adequacy of ventilation by the rocking bed. Most of the patients were given intermittent positive pressure artificial respiration while being transferred from the respirator to the bed and until the bed was actually rocking.

The accompanying Table 1 shows the results of the spirometric tests on the paralyzed patients. Tests No. 1 and No. 2 (Table 1) were done on the same patient to compare the Painter and McKesson beds. The same rate was employed, the head Gatch attachment was elevated 8 inches in each case, and the knees rolled up the same distance. The McKesson bed was tilted to its maximum. The Painter bed was adjusted to tilt the same at the foot and head. Test No. 4 was done on an experimental model of the Painter bed. On this bed the patient lay entirely flat. Comparison of the results in tests 1, 2, 4, and 5 indicated that the two beds produced almost equal ventilation.

It should be noted that in no case did the rocking bed produce as much ventilation as the patient had been getting in the respirator. It is significant that about half of the subjects could not tolerate the bed for more than a few minutes. The average of tidal air in those cases was about 54 per cent of what the patients had been getting in the respirator, whereas those who did not complain of air hunger averaged 77 per cent of the respirator tidal air. The average tidal respiration in the respirator was considerably more than the average tidal air that the rocking bed could produce in this series—383 cc. as compared with 251 cc. These findings are in line with those of Macintosh and Mushin, cited previously, but it should be remembered that the tilt used in the present study was 20° as against 30° and 45° used by Macintosh and Mushin.

To effectively produce sufficient ventilation, the rocking bed should have a tilt of at least 20° each way, 40° total. Greater tilt may be advisable, but the patient tends to slide too much. The supine position seems the most practical for the patient who has impaired breathing due to muscle weakness, but Macintosh and Mushin made the interesting observation that 25 to 50 per cent greater ventilation was

* Respir-aid Rocking Bed, McKesson Appliance Company, Toledo, Ohio.

† Painter Rocking Bed, M. D. (Jack) Painter, manufacturer, 640 South Washington Avenue, Whittier, California.

‡ McKesson Basal Metabalor, McKesson Appliance Co., Toledo, Ohio.

§ The Collins Vitalometer, Warren E. Collins, Boston.

TABLE 1.—*The Ventilatory Capacity of the Rocking Bed*

Test No.	Case No.	Sex	Age	Vital Capacity (cc.)	Tidal Air (cc.) Respirator	Tidal Air (cc.) Rocking Bed	Make of Bed	Reaction to test
1	2	F	23	100	270	200	Painter	Well tolerated
2	2	F	23	100	270	180	McKesson	Well tolerated
3	9	F	35	0	410	160	McKesson	Air hunger in 3 minutes
4	16	M	25	100	390	330	Painter	Well tolerated
5	16	M	25	100	350	300	McKesson	Nausea developed
6	17	M	22	100	470	210	McKesson	Air hunger in 1 minute
7	18	M	35	0	350	250	McKesson	Well tolerated
8	27	M	26	30	500	400	McKesson	Air hunger in 1 minute
9	28	F	27	40	440	230	McKesson	Air hunger after 1 minute
Averages:				63	383	251		

produced on the rocking bed with the patient prone.

The bed frame should be of the Gatch type. The back rest should be rolled up, about 8 inches, the knees about 4 inches. The feet should be snug against the foot-board, and it may be advisable to use shoulder supports. It may also be necessary to support the knees with a strap so that they do not flex as the patient is rocked.

It may be desirable to start the bed rocking in small arcs and then rather quickly increase the degree of tilt to the maximum. The rate of the bed ranges from 14 to 20 per minute for an adult, depending upon the natural rate of the patient's respiration; 18 to 24 per minute for children depending upon age and natural rate of respiration. Frequently, however, the patient's natural respiratory rate is considerably faster than the optimal rate for respiration by artificial means, including the rocking bed.

The time on the bed should be gradually increased from day to day while the patient is observed for any ill effects, especially increase in mucus, chronic fatigue and drop in vital capacity.

Although the ordinary nursing procedures can be done with the bed in motion, it is more convenient to stop it for short periods if tolerated. This also applies to physical therapy, although the rocking motion may help movement in some instances.

CLINICAL EXPERIENCES

At first the rocking bed seemed to offer good possibilities and use of it was begun with considerable enthusiasm. However, the original enthusiasm proved dangerous in some instances.

Altogether during the period of this study 51 patients were placed on the rocking bed. Of these, 23 were at the Los Angeles County Hospital and 28 were at Rancho Los Amigos. They were placed on the bed because it was thought the procedure would aid in reestablishing normal respiratory function. Because of the physical set-up at the Los Angeles County Hospital it was usually necessary to try to transfer the patient from the respirator to the rocking bed permanently. At Rancho Los Amigos, on the other hand, the patient could be transferred back and forth as needed. (The patients at Rancho Los Amigos included those for ventilation measurements already discussed.)

Use of the rocking bed in the County Hospital for the care of patients with acute poliomyelitis was begun on August 2, 1949. During the period of this study 23 patients ranging in age from 3 to 45 years were treated on it for varying periods of time: 14 were males, of whom three were children, and nine were females, one a child. These patients may be divided into an "early" and a "late" group. The early group was composed of six patients who were placed on the rocking bed before or very shortly after being placed in the respirator in the hope that the bed would give them sufficient assistance in breathing that the respirator would be unnecessary. The late group included 17 patients who were placed on the rocking bed ten days or more after being put in the respirator. In addition, three of the patients in the early group were again put on the rocking bed after they had been in the respirator for some time. They should therefore be considered as part of the late group, making a total of 20 in this group.

Of the six patients put on the bed early, only two escaped subsequent respirator care and these two might not have needed respirator care even without rocking bed assistance. One patient probably would have died had a respirator not been available and the three other patients did not do well while on the rocking bed.

When the rocking bed was used later in the disease with the patient afebrile, well stabilized and without complications, the time required to make him entirely independent of the respirator may have been slightly reduced in one-half of the 20 cases cited (see Table 2). However, eight of these patients were already spending three to six hours daily on a flat bed and one, No. 43, had almost full vital capacity before being placed on the bed, while another was spending 12 hours out of the respirator daily before the rocking bed regimen was inaugurated. Therefore, the time saved was probably minimal.

Three of the patients were placed on the rocking bed before ventilation studies were being made routinely. However, all had adequate exchange and good breathing patterns.

Five other patients had approximately one-third normal vital capacity or more. One, No. 46, was placed on the bed to drain a suppurative process in the chest.

On the other hand, five patients who were also afebrile and well stabilized did not improve while on the bed (Table 3) and consequently were returned to the respirators either just at night or around the clock, with subsequent increase in vital capacity.

Table 4 summarizes experience with six patients who were placed on the bed but in whom there developed complications which are described in case reports which follow. However, it is significant that two of the patients, Cases 31 and 36 (who, incidentally, did not do well on three occasions) had very low vital capacities. In two other cases, 32 and 35, increased mucus developed; in Case 35 this resulted in massive atelectasis and necessitated tracheotomy.

Of the 23 patients, ten complained of nausea on one or more occasions while on the rocking bed. This was apparently well controlled by Dramamine,® and only one patient was removed from the bed for this cause alone.

One patient delivered a fetus abortively, two required tracheotomy because of increased secretion of mucus, and one fell off the foot of the bed.

CASE STUDIES

A 25-year-old female patient (Case 29) was admitted on August 5, 1949, with a history of six days of illness with stiff neck, stiff back, fever and sore throat. Weakness of the right arm and shortness of breath had begun the day before admission. On admission it was noted the temperature was 100.4°F., the pulse rate 114, and respirations 40 per minute.

TABLE 2.—*Successful Use of Rocking Bed to Shorten Time of Transition from Respirator to Flat Bed*

Case	Sex	Age	Normal Vital Capacity (Calculated) (cc.)	Time Out of Respirator Before Put on Rocking Bed	Days Since Respirator Care Begun	Date	Time	Tidal Air (Bed at Rest) (cc.)	Vital Capacity (cc.)	Days on Bed	Reason for Removal
47	M	31	.....	20 min. thrice daily	18	.....	.....	Not recorded		7	Recovery
48	M	32	4,700	1 hr. twice daily	22	9-29-49	.....	300	900	6	Recovery
49	M	45	4,380	2 hr. thrice daily	64	12-28-49	.....	.....	1,650	12	Recovery
50	F	26	3,500	2 hr. thrice daily	36	10-12-49	.....	.....	1,150	8	Recovery
						10-20-49	.....	.....	1,400		
						10-26-49	.....	.....	2,600		
57	F	28	3,200	2 hr. thrice daily	16	10-21-49	.....	300	1,150	4	Recovery
						10-22-49	.....	300	1,690		
						10-25-49	.....	375	2,135		
						10-30-49	.....	.....	3,000		
40	M	11	.....	1 hr. thrice daily	14	.....	.....	No record		6	Recovery
30	M	31	.....	20 min. thrice daily	18	.....	.....	No record		7	Recovery
43	M	27	4,200	2 hr. thrice daily	10	3-30-50	9 a.m.	.....	3,150	1	Recovery
							3 p.m.	.....	3,150		
						3-31-50	1 p.m.	650	3,450		
							5 p.m.	650	3,600		
46	M	16	4,200	12 hr. daily		1-17-50	.....	.....	2,390	..	Recovery

TABLE 3.—*Unsuccessful Use of Rocking Bed to Shorten Time of Transition from Respirator to Flat Bed*

Case	Sex	Age	Normal Vital Capacity (Calculated) (cc.)	Time Out of Respirator Before Put on Rocking Bed	Days Since Respirator Care Begun	Date	Time	Tidal Air (Bed at Rest) (cc.)	Vital Capacity (cc.)	Days on Bed	Reason for Removal
37	F	29	3,300	4 hr. twice daily	14	11-11-49	.....	400	1,150	4	No increase in vital capacity. Respirator at night, flat bed during day.
38	F	19	3,200	5 hr.	30	12-10-49	.....	450	1,950	2	Vital capacity dropped to 1,700. Back in respirator except 5 hr. daily on bed.
39	M	22	4,900	3 hr. thrice daily	66	11-16-49	.....	400	1,025	21	Discharged in respirator. Needed respirator at night.
41	M	33	4,560	90 min. thrice daily	39	8- 8-50	8 a.m.	.....	2,050		Respirator at night.
							4 p.m.	.....	1,500		
						8- 9-50	8 a.m.	.....	2,600		Respirator at night.
							4 p.m.	.....	1,900		
						8-12-50	.....	.....	1,800	3	Chest pain.
						8-13-50	8 a.m.	.....	2,175		
						8-14-50	8 a.m.	.....	1,950		Fever, increased pulse and respiration rate. Returned to respirator.
42	M	17	4,500	2 hr. thrice daily	10	10- 7-49	8 a.m.	.....	1,100		Drop in vital capacity. Returned to respirator.

TABLE 4.—*Development of Complications in Well Stabilized Patients Placed on Rocking Bed*

Case	Sex	Age	Normal Vital Capacity (Calculated) (cc.)	Time Out of Respirator Before Put on Rocking Bed	Days Since Respirator Care Begun	Date	Time	Tidal Air (Bed at Rest) (cc.)	Vital Capacity (cc.)	Days on Bed	Reason for Removal
31	F	21	3,100	45 min. thrice daily	18	10- 5-49	.....	275	650		Fatigue.
						10- 6-49	8:00 a.m.	.....	500	1	
						10- 6-49	3:00 p.m.	150	450		
32	F	29	3,000	30 min. thrice daily	21	10- 6-49	.....	400	950	3½ hr.	Increased mucus.
				45 min. thrice daily	26	10-11-49	8:30 a.m.	350			
							3:30 p.m.	275	925	6 hr.	Increased mucus.
33	F	12	.....	15 min. thrice daily	17	.....	.....	No record		9 hr.	Increased pulse.
34	M	7	.....	15 min. 4 times daily	21	.....	.....	No record		14 hr.	Nausea, dizziness, fatigue.
35	M	26	4,900	90 min. thrice daily	14	10-31-49	6:00 p.m.	.....	1,000	3¾ hr.	Increased mucus; tracheotomy.
36	M	27	4,800	.....	33	9- 6-50	.....	.....	350	1 hr.	Breathing 2 to 3 times rocking bed rate.
				30 min. thrice daily	54	9-27-49	9:00 a.m.	200	350	30 hr.	
							9:00 p.m.	75	150		Could not coordinate with rocking bed.
						9-28-49	9:00 a.m.	200	350		
							4:00 p.m.	75	200		

The patient was apprehensive and had pronounced nuchal rigidity. There was moderate spasm and weakness of both upper extremities. The intercostal muscles and diaphragm were weak. The spinal fluid contained 338 cells per cu. mm., all lymphocytes, and the reaction to a Pandy test was 2 plus. At the time of admission the patient could swallow water but shortly thereafter began to have difficulty in doing so. She was placed on the rocking bed at a rate of 18 to 20 per minute about 2 p.m., August 5. At that time the pulse rate was 130, respirations were 39 per minute, and oxygen was being given by nasal catheter. At 8 p.m. the pulse rate was 120 and respirations were 36 per minute. Two hours later the pulse rate was 112 and respirations 28 per minute. It was noted also that the patient slept for very short intervals during the night and in the morning she stated that she was very tired. The following evening the patient began to vomit, the pulse became rapid and faint and the blood pressure could not be measured. At 11 p.m. she was placed in a respirator where she remained overnight. The patient had some difficulty in coordinating with the respirator and the following morning, August 7 at 10:30, she was transferred back on the rocking bed. At this time the pulse rate was 80 and respirations 26 per minute. The rocking bed was running at 18 per minute and the patient finally coordinated with it after an hour or so. On August 9, the rocking bed was stopped for 30 minutes for meals and nursing care, and by August 12 the patient was rocking only from 8 p.m. to 6 a.m. On August 14 the bed was stopped entirely and on August 16 the patient was transferred to a regular bed. A two-and-one-half-month fetus was aborted on the same day. The patient was discharged on August 22, 1949, but with provision made for a standby respirator. At that time the intercostal muscles were weak, the diaphragm fair. There was rather pronounced weakness of both upper extremities and slight weakness of both lower extremities.

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A 31-year-old man (Case 30) was put on the rocking bed on August 2, 1949, after he had been in the respirator four days. He became tired, apprehensive and cyanotic in 45 minutes on the rocking bed and was put back in the respirator. On August 16 he was placed on the rocking bed again, and six days later on a flat bed. (The patient actually falls into both of the previously defined groups, the "early" and the "late.")

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A 21-year-old female (Case 31) was admitted and placed on the rocking bed on September 17, 1949 at 10:30 p.m. Vital capacity at the time was 800 cc. and tidal air 125 cc. The following day the vital capacity was 475 cc. but the patient remained on the rocking bed until September 21, 1949. At that time she was placed in the respirator at negative 18 pressure and ventilated at 450 cc. tidal air. On October 5, after two weeks in the respirator, the patient was again placed on the rocking bed. Tidal air volume at that time was 275 cc. and vital capacity was 650 cc. The following morning the vital capacity was 500 cc. and by 3 p.m. the tidal air had dropped to 150 cc. and the vital capacity to 400 cc. The patient was then put back into the respirator. The rocking bed treatment of this patient in both the early and late phases of the disease was therefore unsatisfactory.

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A 29-year-old female (Case 32) had onset of symptoms on August 30, 1949, with gradually increasing paralysis. On September 14, 1949, partial facial paralysis and difficulty in swallowing were noted. The patient was placed on the rocking bed on September 14 at 1 p.m. and the vital capacity and tidal air volume were improving with the bed in motion. However, it was noted that by 5:30 p.m. there had been considerable deterioration and at noon the next day the vital capacity was 450 cc. The patient was placed in the respirator and tracheotomy was carried out. The patient remained in critical condition, with fainting spells and episodes of bradycardia, but by October 6 her condition was improved and the vital capacity was 950 cc. and the tidal air volume 400 cc. She was placed on the rocking bed for 3½ hours but was removed because of increased mucus. On October 10, the patient was again placed on the rocking bed, but six hours later was returned to the respirator.

* * *

In Case 33 the patient was placed on the rocking bed 17 days after she was placed in the respirator. She remained on the rocking bed for nine hours. Nausea occurred and Dramamine® was given, but the patient was returned to the respirator because of increase in pulse rate.

Twenty-one days after he had been put in the respirator the patient in Case 34 was placed on the rocking bed for 14 hours. He was removed from the bed because of nausea, dizziness and fatigue.

A 26-year-old male (Case 35) was admitted October 16, 1949, after five days of illness, with backache and headache and progressive weakness in the legs for two days, together with inability to cough. The spinal fluid cell count was 94 per cu. mm. and there was positive reaction to a Pandy test. As the condition of the patient deteriorated, he was placed in the respirator on October 17, 1949. The vital capacity at that time was 1,200 cc. By October 31, the patient was out of the respirator one and one-half hours three times daily and was considered a good candidate for the rocking bed. He was placed on the rocking bed at 6 p.m., and at 9:45 p.m. it was noted that there was considerable accumulation of mucus in the trachea. The patient became tired in unsuccessful attempts to cough it up. He was immediately placed back in the respirator. On the following morning it was noted that vital capacity had dropped to 750 cc. and that the breath sounds were absent over the entire left lung. The patient complained of pain in the left side of the chest. In x-ray studies atelectasis of the entire left lung was noted. The same morning laryngoscopy and bronchoscopy were carried out and a large amount of mucus was removed. Two days later, on November 3, the patient became cyanotic with a pulse rate of 140 and with gasping respiration. Bronchoscopy and tracheotomy were carried out and a good deal of mucus was brought up. With positive pressure and aerosol treatment the patient began to improve. He was permitted out of the respirator 15 minutes four times daily for nursing care only. The patient was discharged in the respirator December 2, 1949, to Rancho Los Amigos. At the time of discharge the vital capacity had returned to 1,070 cc. and the patient was permitted out of the respirator 30 minutes four times daily.

Case 36. The patient was placed in the respirator on August 4, 1949. On September 6, 1949, he was placed on the rocking bed. After one hour he was put back in the respirator as he consistently breathed two to three times the rate of the bed. However, it is interesting to note that at the time the vital capacity was approximately 350 cc. Another attempt was made to put this patient on the rocking bed September 27 (see Table 4). Thirty hours later the vital capacity was 200 cc. and the tidal air volume was 75 cc. and the patient was returned to the respirator.

Case 37. A 29-year-old female was admitted September 27. Tracheotomy was carried out and she was placed in a respirator. At that time the vital capacity was 400 cc. and the following day it was 200 cc. The patient began to improve and by November 11, when the vital capacity was 1,150 cc. she was out on a bed four hours twice daily.

The patient was put on the rocking bed to rock alternate hours until 8:00 p.m. and then rock all night. Dramamine® was prescribed. The second day she rocked at night but not during the day, a routine which was continued until November 15. It was then decided at a staff conference that since the vital capacity had not increased materially, the patient would be returned to the respirator for three nights and be permitted to be on a flat bed during the day. This was done and at the end of three days the vital capacity was 1,520 cc. The patient was then left in the respirator for another four nights and the improvement was maintained. She was then placed back on the rocking bed at night until December 5. At that time the vital capacity was 1,600 cc. or approximately 50 per cent of normal and the patient was permitted to sleep on a flat bed with no return to the respirator.

Case 38. The patient was placed on the rocking bed one month after she had been put in a respirator. At this time the vital capacity was 1,950 cc. However, with the patient on the rocking bed the vital capacity dropped and it was necessary to put her back in the respirator at night. Two days later, on December 20, she was returned to the respirator during the day also because it was felt that improvement had not continued. At the time of discharge the patient was spending five hours a day on a poliomyelitis bed and the rest of the time in the respirator. The vital capacity was 1,700 cc.

Case 39. The patient, a 22-year-old male, was first placed in the respirator on September 11, 1949. On September 22, he was placed on the rocking bed. Vital capacity at that time was 500 cc. By September 27 at 8:00 a.m. the patient had become irrational and confused and he was returned to the respirator at 4:00 p.m. Vital capacity then was 300 cc. On November 16, the patient was again placed on the rocking bed. At this time vital capacity was 1,025 cc. and tidal air volume 400 cc. After two days he was put in the respirator at night and on the rocking bed during the day, a routine which was followed until the patient was transferred to a naval hospital, Dec. 6, 1949. Vital capacity at the time of discharge was 1,000 cc.

In Case 46 the rocking bed was used to aid in chest drainage. A 16-year-old boy was placed in the respirator Nov. 16, 1949. There was pronounced involvement of the third, fourth, sixth, seventh, ninth, tenth and eleventh cranial nerves. Suppurative pulmonary disease and right lower lobe atelectasis and pneumonia developed, and the rocking bed was used to agitate the secretions and to place the patient in Trendelenburg position for a short period several times daily so that satisfactory drainage could be obtained. Eventually the rocking bed was substituted at night for the respirator, but at the time it was first used the patient had a vital capacity of 2,200 cc. and was out on a flat bed for 12 hours daily.

Case 41. A 33-year-old male was placed in a respirator July 1, 1950. On August 8 he was out of the respirator one and one-half hours three times daily and doing well. He was placed on the rocking bed at 8:00 a.m. on August 8. Vital capacity then was 2,150 cc. When the patient was returned to the respirator at 4:30 p.m., vital capacity was 1,500 cc. After a night in the respirator vital capacity rose to the previous level and during the following day on the rocking bed it decreased only 200 cc. On Aug. 12 the patient complained of pain in the chest. The vital capacity was 1,800 cc. After 24 hours in the respirator, vital capacity was 2,175 cc. and the chest pain was gone. The patient then was put back on the rocking bed and permitted to rock for 24 hours. At 8 a.m. the temperature was 102.6°F., the pulse rate 134 and respirations 24 per minute, and vital capacity was 1,950 cc. The patient was nauseated. At noon he was put back in the respirator. The fever continued.

The rocking bed was employed as a treatment procedure for 23 patients with chronic poliomyelitis at Rancho Los Amigos. Five of the 23 could not remain as much as 10 minutes out of the respirator. Sixteen patients were able to remain out of the respirator at least several hours but had to be returned

for the night. The remaining two returned to the respirator for occasional rest.

The 23 patients will be considered in three groups. The first consisted of five patients who had a short tolerance time out of the respirator and were put on the bed for periods of up to four hours. In the second group were nine patients who were able to breathe without assistance for at least several hours but still had to sleep in the respirator. In these cases the question was not whether there was adequate ventilation while rocking, but whether there were any possible undesirable side effects. In the third group there were nine patients who tried to sleep on the rocking bed after they had tried the bed during the daytime. They would otherwise have had to sleep in a respirator.

Table 5 gives data on the five patients in the first group. In all of these cases the patient was put on the rocking bed for short periods once daily and the time was gradually increased to the maximum period indicated. The inclination of rocking was 18 or 22 degrees depending on the bed used, although with the first patients the angle may have been somewhat less. The head section of the Gatch frame was raised about 8 inches and the knee section broken about 4 inches. The rate of oscillation varied from 16 to 20 per minute depending on the natural respiration rate of the patient and on the subjective response.

In Cases 2, 5 and 10 the patients tolerated the bed from one to four hours daily but then had to be returned to the respirator because they usually complained of fatigue, although naturally the exact time varied with the general vitality of the patient. These patients had no diaphragm or intercostal strength and it was noted that they assisted the rocking bed action with the use of the accessory muscles in the neck. Hardly ever did these patients nap on the rocking bed. In Case 9 the length of time the patient spent on the rocking bed was gradually increased to about one hour. It was necessary to give her supplementary oxygen. After two or three weeks it was noted that there was a gradual decline in general strength, that the patient was not able to tolerate physical therapy as well as previously and that it became necessary to increase the amount of oxygen. In Case 11 the course was similar. Accumulation of mucus increased and a respiratory infection developed. It was felt that the rocking bed was contraindicated in these cases, although shorter periods might have been tolerated. While out of the respirator and on the bed, these patients received more physical therapy than they had been accustomed to, and this may have contributed to the intolerance. The use of the bed was stopped in the other cases because of reasons other than undesirable effects. In Case 10 the patient was sent home, there to remain in a respirator full-time.

Nine of the patients who were given rocking bed treatment had considerable independence of breathing; all of them could be out of the respirator for several hours (Table 6). With them, it was not at all a question of adequacy of ventilation when on the rocking bed. It should be noted that in one case in this group increased mucus in the trachea was a complication. Treatment periods were one hour once daily.

If the rocking bed could be substituted in cases in which the respirator is required only for sleep, a possible saving in patient care, a more natural situation for sleep, improved morale, and other possible benefits might be expected. With this in mind, nine patients who already had shown good tolerance to rocking during waking hours were considered good candidates for sleeping on the rocking bed. All of the nine patients except one (Case 20) had been using the rocking bed, while awake, for weeks. In most cases the period of rocking was increased to five or six hours into the sleeping hours before the patient was permitted to sleep on the bed through the night. The patients were observed closely for any signs of loss of sleep, progressive fatigue and drop in vital capacity.

Table 7 summarizes the observations in these cases. It should be noted that the vital capacity of these patients was 300 cc. or more at the beginning of this study. The patients could usually sleep well even though most breathing was largely by neck accessory muscles. With a small amount of diaphragm action, other conditions being equal, it would be expected that sleeping on the rocking bed would be much easier. This is in accord with repeated clinical observations on patients who try to sleep without the aid of artificial respiration. All of the patients except one (Case 20) would have needed the respirator for sleep if it had not been for the aid produced by the rocking bed.

One patient (Case 7) required the use of the res-

TABLE 5.—*Rocking Bed Tolerance with Short Tolerance Out of Respirator*

Case	Sex	Age	Onset	Date Rocking Bed Started	Date Rocking Bed Stopped	Tolerance Out of Respirator	Maximum Tolerance on Rocking Bed	Stabilized Vital Capacity (cc.)	Remarks
2	F	23	8-10-48	8-22-49	5-50	5 min.	4 hr.	100	Patient transferred
5	F	35	6-25-48	11- 2-49	5-50	5 min.	1 hr.	100	Patient transferred
9	F	35	11-15-48	11- 2-49	12-19-49	3 min.	1 hr.	0	Did not tolerate
10	M	25	11-15-48	11- 2-49	1- 5-50	2 min.	1 hr.	100	Discharged home
11	F	27	11-15-48	11- 2-49	12-16-49	10 min.	1 hr.	250	Did not tolerate

TABLE 6.—*Rocking Bed Tolerance with Long Tolerance Out of Respirator*

Case	Sex	Age	Onset	Date Rocking Bed Started	Vital Capacity (cc.)	Remarks
1	F	37	8- 2-48	8-22-49	300	No undesirable effects—still uses bed.
3	F	33	10- 9-48	11- 9-49	300	No undesirable effects—still uses bed.
4	F	28	9- 4-48	11- 9-49	750	No undesirable effects—discharged February 1950.
8	F	38	9-15-48	11- 9-49	900	No undesirable effects—now once weekly.
13	M	5	10-14-48	8-49	400	No undesirable effects—stopped December 1949.
14	F	27	7-14-48	8-49	1,000	No undesirable effects—stopped December 1949.
15	M	42	11-13-48	8-49	700	Tried only few times—patient did not like it.
19	F	21	9-28-48	4- 7-50	350	Tolerated—but increased mucus.
23	M	16	7-31-48	11- 2-49	600	No undesirable effects.

TABLE 7.—*Substitution of Rocking Bed for Respirator When Respirator Used Only at Night*

Case No.	Sex	Age	Onset	Date Rocking Bed Started	Vital Capacity (cc.)	Date Rocking Bed Stopped	Vital Capacity (cc.)	Breathing Pattern	Remarks
6	M	17	8-28-48	3-20-50	470	Continued	600	Neck chiefly, some chest, no diaphragm	Sleeps well on rocking bed
7	F	31	7-11-48	1-12-50	300	1-26-50	400	Neck accessories only	Slept poorly, very tired
12	F	34	11-11-48	12- 2-49	400	12-23-49	1,400	Weak chest and diaphragm; some neck accessory action	Slept well but tracheal bleeding
20	M	18	3-20-50	5-31-50	2,000	6- 6-50	2,300	Good pattern, slight weakness	Transition from respirator to bed
21	M	22	11-18-49	7-10-50	1,350	10-20-50	1,350	Weak diaphragm and chest, uses neck	Transition from respirator to bed
22	M	19	7-22-48	11- 7-49	400	1-13-50	400	Uses neck only	Slept well; discharged with respirator
24	F	33	11- 4-48	2-28-50	700	5- 9-50	700	Weak diaphragm and chest, uses neck	Slept well; transition from respirator to bed
25	M	7	11- 8-48	5- 2-50	480	5- 8-50	480	Nearly all neck accessory action	Slept well but temporary complications
26	M	14	10-10-48	1-16-50	400	Continued	600	Nearly all neck accessory action	Sleeps well

pirator with a very high negative pressure (35 cm. of water). This was sufficient to produce over one liter of ventilation. It is plain that if the patient were to breathe this amount of air continuously at each breath, alkalosis and tetany would soon develop. This was prevented by the patient by throttling all but every third or fourth breath so that on the average she would breathe the proper amount. The respirator pressure used in this case is difficult to maintain and with it there is a possibility of damage to the cardiorespiratory system. For this reason attempt was made to break this peculiar breathing mechanism by having the patient sleep on the rocking bed. The patient was able to get some sleep, but she became progressively insomnic and signs of exhaustion appeared. In spite of the poor clinical effect, the vital capacity increased. However, the rocking bed for sleeping was discontinued.

Although in Case 12 the patient slept well, tracheal bleeding of unknown origin developed while the rocking bed program was being followed, so it was decided to discontinue the procedure.

In Cases 6, 20, 21, 22, 24, 25 and 26 the patients appeared to tolerate the rocking bed well for sleeping at night; and two of these patients (Cases 6 and 26) are still using it. In Cases 20, 21 and 24 the bed was used to advantage in weaning from the respirator. In Case 22 the rocking bed had to be discontinued when the patient was discharged home where he uses a tank respirator. In Cases 25 and 26 the patients had to return to use of the respirator temporarily because of complications apparently not related to the rocking bed. In Case 25 use of the rocking bed was discontinued because it had to be removed from the ward.

About half of these nine well stabilized patients with chronic poliomyelitis had an upward trend in vital capacity while on the rocking bed.

DISCUSSION

These clinical observations on patients with weakness of respiratory muscles, as well as accepted physiological principles point to the concepts which should be considered in the use of the rocking bed when there is appreciable weakness of the muscles of respiration.

Ordinary breathing consists of the tidal ventilation of air in and out of the lungs. The ventilation per minute is determined by the rate and depth of breathing. This volume is precisely controlled by the respiratory center which in turn may be influenced directly or reflexly by various factors such as oxygen and carbon dioxide tensions of the blood plasma, blood bicarbonates and pH, certain hormone-like substances, the Hering-Breuer reflexes and a number of drugs. Pulmonary ventilation has two important functions: One is to maintain the proper oxygen tension of the blood; the other is to aid in maintaining the proper blood pH. Hyperventilation produces blood alkalosis (respiratory alkalosis) because the carbon dioxide is worked out of the lungs but no appreciable increase in blood oxygen tension or increase in oxyhemoglobin saturation occurs. Inadequate ventilation produces relative acidosis (respiratory acidosis) resulting from an accumulation of carbon dioxide and a decrease in blood oxygen tension associated with a decrease in the oxyhemoglobin saturation. Deficiency of ventilation does not decrease the oxygen requirements of the tissues except in the terminal stage of asphyxiation (anoxia) and possibly in chronic anoxia which is sufficiently prolonged and intense to produce tissue deterioration.[5] In the presence of a normal cardiorespiratory system, adequate strength of the respiratory muscles, a normal regulatory system and adequate oxygen, the oxygen supply to the tissues is ample over a wide range of conditions and the blood pH is maintained within narrow limits (pH 7.35 to pH 7.45). In the presence of weakness of the respiratory muscles this system may break down, although a certain amount of compensation—increase in pulse rate and in the bicarbonate content of the blood—takes place. In the presence of good nutrition there may be an increase of hemoglobin, but the tendency is toward anemia.

There is considerable clinical evidence that prolonged mild anoxia and exhaustion associated with pronounced weakness of the respiratory muscles in poliomyelitis will lead to general tissue deterioration especially of the brain and the gastrointestinal tract. This seems to result especially from inadequate exchange of oxygen and carbon dioxide during the sleeping hours. Some of these observations have been emphasized in a previous publication.[2]

The most important muscle of respiration is the diaphragm. Sudden bilateral phrenic nerve paralysis is very serious unless the patient is given adequate artificial respiration. The muscles that produce expansion of the lower chest function chiefly in preventing chest collapse when the diaphragm acts. The most automatic pattern of breathing is that carried out by the action of the diaphragm together with expansion of the lower chest. This is normally the chief component of what may be termed "unconscious breathing." The muscles that expand and raise the upper chest also take part in quiet breathing but to a lesser degree. If there is sufficient weakness of the diaphragm so that it cannot easily maintain the required ventilation, the muscles that expand and raise the chest increase in their action. If this action is inadequate, the accessory muscles in the neck in turn come into action and the muscles producing chest and abdominal compression may eventually assist breathing. Just which muscles are used depends on the required tidal air, on general and individual muscle strength, on the wakefulness of the individual and on habit patterns that have been developed.

If the patient has to depend to an appreciable degree on accessory muscles for quiet breathing, it is usually difficult for him to sleep, since "unconscious breathing" usually requires the use of the diaphragm and lower chest muscles. Such a patient may "subconsciously" use various accessory muscles during the waking hours and have sufficient ventilation. In a certain number of cases accessory patterns of breathing seem to become well linked to the respiratory center and become automatic "unconscious breathing," so that breathing with accessory muscles while asleep may be adequate. In such circumstances, however, great care should be taken lest the chronic effects of partial asphyxia develop because of inadequate muscle strength or insufficient automaticity. If accessory action is not well established for sleep, the cerebral and somatic functions may so deteriorate that the patient may even die unless he is given adequate artificial respiration, especially while sleeping.

Tests by the authors as well as those of Macintosh and Mushin indicate that the rocking beds that were used did not produce the tidal air required for quiet breathing in cases of complete paralysis. In contrast, the tank respirator is capable of producing about two times the basal tidal air required in most cases. Therefore, it appears that the rocking beds tested can be safely used during sleep only in those cases in which there is at least an appreciable amount of "unconscious" or automatic breathing, and during the waking hours only if the patient is able to sufficiently supplement the effect of the bed by subconscious effort without signs of fatigue or impairment.

CRITERIA FOR USE OF THE ROCKING BED

On the basis of the physiological concepts and clinical observation described in this report, the rocking bed can be used for the purpose of assisting respiration in cases in which there is weakness of the respiratory muscles. It should not be used during the febrile period of poliomyelitis, nor in the presence of secondary complications such as atelectasis, pneumonia, upper respiratory tract infection and urinary infection.

The rocking motion may cause motion sickness, as manifested by nausea and dizziness, especially if the bed is used soon after the occurrence of paralysis. Dramamine® is of value in the prevention of this complication.

It has been observed that the rocking motion tends to increase the amount of mucus in the respiratory tree, particularly during the first few hours, but the explanation is not clear. If the patient tends to have an increase in mucus as in respiratory infection and moderate bulbar involvement, the rocking bed may be contraindicated, especially in the absence of tracheotomy. Any patient when first placed on the rocking bed should be given individual nursing care and should be closely observed for increased mucus and possible occlusion of the bronchi.

The programs followed by the authors for placing patients on the rocking bed varied to accord with the facilities for special nursing care and in consideration of whether the patient was in an early stage of the disease or had had it for a number of months. Observations indicated that the following considerations and methods make for the best rocking-bed program for patients during the first few weeks after the febrile period:

1. The patient should be able to be out of the respirator at least one hour three times daily without the use of the accessory muscles and with no increase in pulse rate or other untoward reaction.

2. The vital capacity should be at least one-third of the normal standard, and there should be record of a consistent increase with at least one-half of the vital capacity due to diaphragmatic action, before a patient is considered for rocking-bed treatment.

3. When the patient is on the rocking-bed program, the vital capacity should be tested twice daily for several days, and daily thereafter. If it decreases, return to the respirator is indicated.

4. The daily schedule should begin with six to eight hour periods on the rocking bed, with the patient returned to the respirator at night. If there are no ill effects and the vital capacity does not decrease, the patient then may be permitted to sleep on the rocking bed.

Patients who in the early stages of the disease do not meet the criteria for being put on the rocking bed, may later do well with this treatment even though they then may have much lower vital capacity.

Between the eighth week and the eighth month, when muscle function is still returning, the patient ordinarily should not be permitted to use the accessory muscles of breathing. If during that period he is able to be out of the respirator for as much as 15 minutes at a time without using accessory respiratory muscles, the rocking bed can usually be well tolerated during the daytime, provided the time he spends on the bed is not too rapidly increased.

Some patients who need to use the accessory respiratory muscles because of moderate weakness of the diaphragm and intercostal muscles may do well on the rocking bed for short periods, but they should be closely watched.

If, after six to eight months, there appears to be no appreciable return of diaphragmatic strength, it is usually advisable to permit the patient to use the neck or other accessory muscles when he is out of the respirator. If it appears early that there is little likelihood that diaphragm function will improve, the period of trial may be shortened somewhat. A patient who has no return of chest and diaphragm muscles should develop the strength of the accessories. Usually if there is no weakness of the accessory muscles the patient is able to remain out of the respirator all day. The vital capacity in such a case should be at least one-tenth normal. Usually, however, a patient who depends upon the action of accessory muscles cannot breathe while asleep unless assisted by a respirator or rocking bed. It appears clinically in such cases that the respiratory center takes over during sleep with difficulty. Great care should be taken before such a patient is permitted to sleep on the rocking bed, since the bed only assists in the volume of breathing. It is important to follow the progress of the patient carefully with regard to general vitality, appetite, nutrition, mental alertness, vital capacity, and development of disturbing symptoms such as headache.

The following guides would seem to be applicable for use of the rocking bed for patients six months or more after onset of the disease — always with recognition, however, that they must be modified in event of development of certain side reactions such as nausea, vertigo, accumulation of mucus, and signs of fatigue, exhaustion and anoxia including changes in pulse rate, lassitude, loss of appetite and decrease in vital capacity:

1. If the patient has no vital capacity and cannot be out of the respirator more than three minutes, use of the rocking bed is not feasible.

2. If the patient is able to be out for more than three to five minutes, especially if there is fair function of the diaphragm, he can usually be put on the rocking bed for increasing times, up to several hours.

3. If the patient is able to be out several hours on his own strength, there should be no difficulty whatsoever in placing him on the rocking bed, for any desired time, during the waking hours.

4. If the patient is able to be out of the respirator all day without any difficulty, especially if vital capacity is over 10 per cent of normal and at least half of this is due to diaphragm action, then he should be able to sleep on the rocking bed. In some cases even patients who depend entirely on accessory muscles for breathing do well sleeping on the rocking bed. It is important that conversion to sleeping on the rocking bed be done gradually and that vital capacity be checked daily for the first two or three days. All patients, and especially those who depend on accessory muscle action, should be watched very carefully for signs of intolerance.

REFERENCES

1. Carson, L. D., and Pinto, J. C.: The Eve method of resuscitation, U. S. Naval M. Bulletin, 47:650, 1947.

2. Dail, C. W., Bennett, V. R., and Bower, A. G.: Measurement of respiratory deficiencies in poliomyelitis, Arch. Phys. Med., 31:276, May 1950.

3. Eve, F. C.: Actuation of the inert diaphragm by gravity method, Lancet, 2:995, 1932.

4. Eve, F. C.: Resuscitation of the drowned today, J.A.M.A., 124:964, 1944.

5. Henderson, Y.: Adventures in Respiration, Williams & Wilkins Co., 273-277, 1938.

6. Lenarsky, M.: The rocking bed—its use in poliomyelitis, Archives of Pediatrics, 66:339, 1949.

7. Macintosh, R. R., and Mushin, W. W.: Pulmonary exchange during artificial respiration, Brit. Med. Jr., 1:908, 1946.

8. Sanders, C. E.: Cardiovascular and peripheral vascular diseases—treatment by a motorized oscillating bed, J.A.M.A., 106:1916, 1936.

9. Wright, J.: The respir-aid rocking bed in poliomyelitis, Amer. Jr. of Nursing, 47:454, 1947.